SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ADA036248

12

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
Unnumbered

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
6 Balloon Command-Control, Final Report

5. TYPE OF REPORT & PERIOD COVERED
Final Report
8/1/75 - 7/31/76

6. PERFORMING ORG. REPORT NUMBER
N/A

7. AUTHOR(s)
P. Roger Williamson
10

8. CONTRACT OR GRANT NUMBER(s)
15 N00014-76-C-0258

9. PERFORMING ORGANIZATION NAME AND ADDRESS
University of California, San Diego
P. O. Box 109
La Jolla, California 92037
16 RR03303

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
17
61153N, RR 033 03 01
NR 211-185

11. CONTROLLING OFFICE NAME AND ADDRESS
Office of Naval Research, Code 465
Arlington, VA 22217

12. REPORT DATE
11 7 Jan[redacted]77

13. NUMBER OF PAGES
22

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
12 21p.

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
N/A

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited

DDC
MAR 2 1977

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
9 Final rept. 1 Aug 75 - 31 Jul 76

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Scientific Balloons; Balloon flights; Telemetry; Balloon Control; Flight Termination

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
Testing and modification of a low-cost expendable flight termination device for small balloon operators. This is a tonal control transmitter/receiver system using phase-locked loop circuitry to insure safe interference free operation. Design circuitry included.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

012 320

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

University of California, San Diego

BALLOON COMMAND-CONTROL

Final Report
1 August 75 - 31 July 76

N0014-76-C-0258
NR 211-185

January 7, 1977

P. Roger Williamson, Principal Investigator

BALLOON COMMAND-CONTROL

Final Report

This is a final report on Contract N00014-76-C-0258, NR 211-185/8-15-75 (465), for the period 1 August 1975 to 31 July 1976.

At the end of this contract period we have accomplished the following tasks as set out in our original contract and the contract expansion:

- Receiver decoder board was modified (MOD B)
- Auto-ranging prototype circuit built and tested
- Walkie-talkie acquired and command encoder plug-in fabricated.
- Modify auto-encoder for ground station
- Built and delivered 10 command receivers to Raven Industries.
- Participated in flight test at Raven
- Flight tested five receivers in Alaska
- Patent application was submitted by the Pasadena office.
- Parts acquired for a revised PCM add-on system

Decoder Board Modification

A new layout of the decoder board for the command receiver was made and incorporated the changes called MOD B. After receiving objections to the low battery firing circuit addition prepared before MOD B was finalized, we omitted this feature and returned to the redundant firing circuit as originally designed and added a Gates battery pack for high reliability. The two squib firing circuits are not tied together internally providing only one squib connection to the receiver. Several of the telemetry outputs not required on operational units were omitted.

These MOD B revisions are described in the operating instructions for command receivers with serial numbers 76-001 through 76-014 and distributed to interested parties in July, 1976. A copy of these instructions, which include the MOD B schematic, is attached.

Auto-Ranging Ground Station

Emphas s in the program was placed on developing the auto-ranging circuits and display. A prototype circuit was built and tested at Raven on 30 July 1976, and on five operational flights from Ft. Wainright, Fairbanks, Alaska, in late September, 1976. The techniques employed were demonstrated and verified on these flights. The present command receiver can be used with an automatic ranging system to provide a display at the touch of a button of the one-way slant range to the balloon in statute miles to the nearest tenth mile. System path delays are automatically subtracted from the display after initial offset correction before launch. Thus, at the time of launch the display would read 0.0 sm if the balloon was within 0.1 sm of the telemetry ground station. During the flight test by Raven from Sioux Falls, South Dakota, agreement of ± 5 nm between the Raven system and the command receiver system was demonstrated. In Alaska, the payload from our first flight was found within 1 sm of the last slant range measured - 145 sm. The parachute winds should have taken the payload perpendicular to the azimuth from the telemetry ground station indicating that the slant range measurements again were within ± 5 nm.

While the automatic system works at the touch of a button after the initial set-up, difficulties still exist in the total operation of the system and particularly the initial set-up of the prototype ground station. As a result of our experience during the Raven flight and the Alaska flight series, we have identified one minor change in the command receiver and several improvements in the ground station which should result in a truly simplified operation. The final modification to the decoder board which appears necessary is an increase in the audio output by adding gain to the buffer amplifier output. This change (MOD C) will be implemented during our 1977 contract period at Utah State University. This change will have no effect on the squib firing circuitry. Modifications to the ground station include a change in the power supplies to permit operation from a single 12-volt power source and, most importantly, changes in the stop detection circuitry so that zero crossing instead of level detection is used to detect the return signal. This last change should remove much of the ± 5 nm error in the recent flight tests which are ascribed to small level shifts in the detector circuit, telemetry and signal amplitude. In addition, zero cross detection will greatly simplify the set-up requirements for the system.

Walkie-Talkie Acquisition

A General Electric 5-watt hand-held radio was acquired with two channels set for the same frequencies as the 100-watt mobile transceiver. The balloon command and voice frequencies of 138.54 MHz and 138.84 MHz are designated as channels 1 and 2, respectively, and command receivers can be built for operation on either of these two frequencies.

A squib command encoder was constructed in a small box which plugs into the external control jack of the hand-held radio permitting simplified testing at lower power of the receivers and a back-up means of sending a squib command in the event of failure in the 100-watt station. The command capability of the hand-held unit was demonstrated in Sioux Falls with the balloon at a distance of about 80 nm. In both Sioux Falls and Alaska, we found the hand-held unit was very useful for both flight line check-out and communications.

Auto-Encoder Squib Command

A modification was made to the ground station squib command encoder to improve the sweep range and sweep rate, however, the wave shape is still not as good as achieved using an external sine wave oscillator manually swept.

Ten Receivers Delivered For Testing

After the contract expansion was initiated, receivers were built with the assembly performed by Lark Engineering of Newport Beach, California. Lark Engineering has expressed an interest in performing all manufacturing functions for receivers in the future for those who wish to use an outside source. (Instructions on construction of these receivers and a pc board negative are available from us for qualified users. Inquiries should be directed to ONR (Code 465)). Ten receivers were delivered to Raven for environmental chamber and flight testing. In the process of assembly and testing, one bad receiver was found and returned to Plectron for repair. The receiver board had a bad second I.F. crystal which was replaced without charge. Receiver 76-003 was returned to UCSD from Raven as defective. The problem was traced to a combination of two simultaneous faults - a missing fiber spacer and an extra unneeded jumper wire (W8) on the P700 receiver board. All of the other receivers checked so far have the fiber washer in place but also have the W8 jumper which has since been removed. The three remaining receivers returned by Raven have not been checked although only one of them has symptoms indicating the same problem. One of the receivers yet to be checked was returned because of a low receiver sensitivity of 1.0 μV instead of the normal 0.4 μV. Except for testing in the lab with proper instrumentation, this receiver probably would not be noticeably different than any other normally operating receiver.

Flight Test at Sioux Falls

In late July, we participated in a flight test conducted by Raven at Sioux Falls, South Dakota, on July 30, 1976. Several changes had been made in the command system. The aluminized mylar wrapped inside and outside the foam boxes had been removed and replaced with a different outside wrap. It is not known what differences, if any, in the thermal behavior of the package--particularly during night time flights--could be attributed to this modification. An important change in the electrical circuit was made by Raven personnel who connected the telemetry VCO directly to the receiver discriminator output at TP2 on the receiver board thus bypassing the audio output amplifier, the RFI filter circuits and the 2.5 V dc offset added by the output buffer amplifier to permit compatibility of the audio output with the 0 to +5 volt input range of the VCO's. Except for operation of the ranging system, no adverse effects from this modification are apparent in the results of the flight tests. Further comments related to the Raven test report are included in a later section.

As described in our flight report, the receivers were successfully commanded throughout the flight both by the 100-watt ground station and the 5-watt walkie-talkie. Ranging agreed with the Raven system within ± 5 nm.

Alaska Flight Series

In late September 1976, we used five command receivers (3 belonging to the project and 2 from the ten test units) on flights from Ft. Wainright, Alaska, in cooperation with Prof. J. R. Barcus of the University of Denver, and Dr. George Parks of the University of Washington, Seattle. The three receivers used by Jim Barcus and I were mounted inside the payload styrofoam box and the audio was retransmitted on a Channel F subcarrier. Ranging and cutdown were successfully performed on all three flights. The audio buffer amplifer was modified to provide a gain of five to increase the audio signal to noise ratio.

Two receivers were provided to Dr. Parks and were connected directly to an S-band transmitter input through a blocking capacitor. The command receivers utilize a self-contained battery power supply and cut-down functioned on both flights. On the second flight, an apparent battery failure in the S-band transmitter resulted in a loss of ranging during the latter portion of the flight.

After the two launches for Dr. Parks, operation of the ranging and command system was performed by Dr. Parks and his associates.

Although the primary purpose of the ranging system is not for recovery, we attempted to use the range and azimuth information for recovery on both of the flights for Dr. Parks after problems developed with the recovery beacon system. On Dr. Parks' first flight, problems were experienced in determining the correct azimuth for the balloon at cut-down. The S-band receiving dish was receiving the balloon through the aircraft control tower at the time of cut-down so the dish pointing direction may have been influenced by reflections from the tower structure. An additional difficulty arose in determining the pointing direction with respect to true north since the S-band antenna mount did not have a compass rose. An error of $\pm$ 10^{o} in the azimuth is equivalent to $\pm$ 26 sm at 150 sm where cut-down was initiated. If a ranging error of $\pm$ 5 sm is assumed, the search area is 520 square miles in size not including drift on the parachute.

On Park's second flight, the S-band transmitter stopped transmitting about halfway into the flight so no ranging information was received. A search aircraft flew a pattern in the estimated cut-down area but did not observe the descent. As of this date, neither of these payloads has been recovered.

Patent Application

A patent application was submitted by the ONR Pasadena office on "A Sliding-Tone Command Receiver System."

PCM Command System

The PCM command system add-on package received less emphasis during this period than other portions of the program--particularly the ranging system. We have, however, bench tested a CMOS digital word command system in two different configurations and have decided to redesign the system using a new low-power UART integrated circuit which will include a number of advanced features including parity and frame error checks.

Summary and Recommendations

The principal objective of this project has been the development of an expendable low-power command receiver system. Recent emphasis has been given to the inclusion of a ranging system. Both the command and ranging system have been successfully demonstrated with no failures attributable to the command receiver. In only one case has a command failed to be received and this case I attribute to a lack of familiarity with the command system and not the receiver. During Raven flight number 1390, receiver 76-008 did not receive a command when the receiver temperature was -28^{o} C although after the temperature increased to -25^{o} C, a command was accepted. No mention is made of whether or not the retransmitted audio signal was received during this period which would indicate the proper operation of the P700 receiver board. Our experience on several flights and during chamber tests has shown some drift in frequency of the PLL does occur. The great advantage of using a sliding-tone command instead of a two-tone narrow bandwidth technique is that temperature and component changes of the PLL frequency can be compensated for easily by sliding the command tone over a wide range while simultaneously retaining the narrow band capture range advantages of high sensitivity and low false triggering probability. To date, not a single false triggering of the command receiver has been observed which could be attributed to the sliding-tone technique.

As observed in the Raven report, problems have been observed when walkie-talkies were used in the close vicinity of the receiver. The problem is not in the SCR firing circuit but occurs between the PLL output and the high impedance input of the level detector circuit. High levels of RF in this area trigger the level detector which starts the UJT timer firing the SCR as in a normal command sequence. The command receiver is mounted in a shielded box and RF is entering the box through the external wiring. I have now added sections of an RF absorbing material around the wiring which has greatly reduced the susceptibility to accidental triggering. A walkie-talkie can now be operated within five feet of the receiver and associated wiring without triggering a squib firing.

The 40 percent failure rate in bench and lab testing quoted by Raven for the ten receivers sent to them is somewhat misleading if used as an indicator of the command receiver reliability for flight use. Receivers 76-001 and 76-003 apparently both failed because the fiber washer was omitted and jumper W8 was not removed. Two corrective actions have been taken to prevent this failure mode in the future. All characteristics of the failure are understood and 76-003 was repaired as indicated and flown in Alaska.

Receiver 76-005 was returned for a sensitivity of 1.0 μV instead of the nominal 0.5 μV--a problem which would probably not affect cutdown since a large margin in signal to noise ratio is maintained throughout the system for just such an occurrence. On this note, it should be observed that the antennas have not been tested (except during design and fabrication) and normally contribute a large and variable source of signal loss.

Receiver 76-011 operated properly in the bench test and was returned because the "squib time delay" was 31 seconds which was deemed too long. The 30 second maximum specification for the timer, however, does not include the delay associated with the ground station which is about 15 seconds or more depending upon the PLL center frequency. Thus, receiver 76-011 is operational without any further testing.

The difficulties in using the command system point out the need for onsite training of users so that similar problems are minimized in the future. This requirement is apparent from both the Sioux Falls and Alaska flight series and should substantially increase the reliability of the <u>total</u> system which is required to produce successful termination of a balloon flight.

With respect to the use of a sealed lead-acid battery for powering the command transmitter, we have used this system for all in-house testing, one flight at Holloman AFB, two flights in Peru, and five flights from Alaska and find it satisfactory with the advantages of low cost, light weight and high reliability. We find no reason not to continue with the battery system for our own use in the future.

Future Plans

A follow-on contract at Utah State University will su rt continued development of the Lightweight Command Receiver system. In the coming years, we plan on accomplishing the following objectives:

(1) Modify the command decoder board for increased audio output in order to increase the signal-to-noise ratio on the VCO telemetry link.

(2) Recable and repackage the transmitter for field operations.

(3) Modify the automatic encoder for sine wave operation. This will require the ground-based transmitter and walkie-talkie ranging circuit to be modified. This modification will make operation substantially less susceptible to poor adjustment of tuning by the operator and increase reliability.

(4) Develop an S-band dish mount with encoders which will allow for direct readout of azimuth and elevation.

P. Roger Williamson

ATTACHMENTS

UTAH STATE UNIVERSITY

CENTER FOR RESEARCH IN AERONOMY
UMC 41
Logan, Utah 84322
Phone: (801) 752-4100 Ext. 7879, 7870

EXPENDABLE COMMAND RECEIVER

The enclosed material is a preliminary documentation for a balloon command receiver developed at UCSD for ONR. The PC board layout and component location overlays have been modified to incorporate the MOD B revision of the schematic. The only TM outputs will be the buffered and DC offset audio, the squib connect signal which also serves as the battery voltage monitor and a temperature monitor. A brief description of the circuitry follows.

The audio signal at the discriminator output TP2 of the P700 board is AC coupled to a COSMOS phase-locked loop. PLL parameters are chosen to require a slowly swept tone (t ≈ 10 sec., 250 Hz to 350 Hz) in order to lock up the PLL and raise the phase comparator output to a level which will trigger the level detector —comprised of 1/3 of the L144AP triple, low-power op amp. The level detector output then goes high and charges the gate capacitor of a unijunction transistor circuit. The UJT time constant is about 3 seconds and the output pulse triggers a SCR. The SCR grounds the squib which is connected between the SCR and the positive side of the battery.

P. Roger Williamson

OPERATING INSTRUCTIONS

COMMAND RECEIVER

July 1976

P. Roger Williamson

Office: Center for Research in Aeronomy
UMC 41
Utah State University
Logan, Utah 84322

Office Phone: (801)752-4100 Ext. 7879

Home Address: 180 Summit Drive
Smithfield, Utah 84335

Home Phone: (801) 563-5996

OPERATING INSTRUCTIONS

This instructions apply to UCSD/ONR Command Receiver Serial Numbers 76-001 through 76-014.

Testing

A battery capable of supplying 30 milliamps at 10-15 V for the flight duration is connected to the RED wire (positive side). There is a 12,000 microfared capacitor inside the receiver which will produce a very large current surge when the battery is connected. If a 100 ohm resistor is connected between the positive battery terminal and the red wire before they are connected, then the large current surge is avoided.

For testing, a small lamp (e.g. Dialco 14 V, 80 milliamp) should be connected between the RED (positive) wire and the WHITE wire (the "squib" is fired by turning on an SCR which 'connects' the white wire to ground.) If the battery voltage is below ~9.7 V the receiver will become inoperative.

Check the operation of the squib command with a normal battery voltage (10.0-15.0 V) by transmitting a sign or square wave tone of 250 Hz and slowly increasing the frequency to 350 Hz (or about 50 Hz above the PLL center frequency). Experimentation with the sweep will show how fast the transition can be made from 250 to 350 Hz. For a weak RF signal the transition should not be made in less than about 10 sec. Multiple tests can be made without turning off the receiver by momentarily disconnecting the light. The SCR will drop out of conduction if current is interrupted and not turn back on when the light is reconnected.

Orientation of the command receiver and placement are not critical. However, the antenna must hang vertically and should be at least one antenna length away from metal. The braided shield is part of the antenna proper and must also be vertical and away from any metal surface.

At this point the buffered audio output from the receiver should be viewed and checks made for RF interference and full quieting on low RF power transmissions. If the transmitter is run into a dummy load and placed some distance away from the receiver, full quieting should still be observed. With a weak command transmitter RF signal, any interference from the on-board transmitters and electronics should be apparent. Test command should be sent and received under these conditions. The results of the test can be confirmed at the telemetry receiving station if the audio and squib telemetry outputs of the command receiver are transmitted on the down-link telemetry.

Flight Turn On

A final test is made just prior to connecting the squib as follows:

1. The command receiver (blue wire) is turned on by connecting to the battery (red wire).

2. A light is connected between the red and blue (positive battery) wires and the white (squib fire) wire.

3. Observe the audio and squib signals from the telemetry and confirm the light on at the payload.

4. Disconnect the light momentarily to turn the circuit off.

Squib Connection Procedure

1. Connect the battery to the receiver.

2. Check the squib firing line with test light.

3. Connect the squib.

Turn-off Procedure

If the squib is connected to an active receiver, the receiver cannot be turned off without firing the squib. Thus, the squib must be disconnected before the command receiver battery is disconnected.

Wiring

RED - positive battery and squib

BLUE - receiver power in

WHITE - squib

Telemetry Output (when available)

Channel Number	Color	Function
1	white	Temperature
2	white	Audio (dc offset = 2.5 V)
3	white	Squib & battery voltage (Note*)
-	green	Signal ground

*When the squib is connected, the battery voltage x 1/3 appears at the channel 3 output. When the SCR fires, the squib opens and 0 volts appear at the channel 3 output. Thus, this channel indicates both the battery voltage (which must be 3.3 volts at the TM output or greater) and the state of the squib.

Ranging

Field tests have shown that the slant range to the balloon can be measured using the ranging capability of the command receiver with a random error of ±0.1 nm. The absolute accuracy depends upon the temperature stability of phase shifts in the down-link TM system assuming the sub-carrier bandwidth is large enough for faithfully retransmitting the audio output of the reciever.

The slant range is determined by measuring the time delay of a 250 Hz square wave which is transmitted on the command receiver frequency and received on the down-link telemetry. If the discriminator output of the audio channel is observed on an oscilloscope and the outgoing square wave is used to trigger the horizontal sweep, then the delay time can be measured. Signal inversion may occur some place in the loop and care must be taken in determining the correct "transition" to use in measuring the delay time. The correct transition is easily found because it will not move on the scope display if the square wave frequency is varied.

Calibration of the inherent system delay must be done before launch with all components of the system operating. If an oscilloscope with a time delayed horizontal sweep is available (e.g. Tektronix 454) the measureing process can be made very simple. The scope can be set up so that the variable time delay knob reads in units of 2 microsec. In this case, since the distance to and from the balloon is twice the slant range, the dial reads approximately the slant range in thousands of feet, i.e., 2 μsec = 1 dial divisions = 1,000 ft. Of course, the system time delay must be subtracted to determine the actual slant range.

An automatic ranging system is under development which subtracts the system time delay, converts the time delay to distance and displays the slant range in units of nm, statute miles or kilometers to the nearest 0.1 unit. The automatic system also incorporates a period averaging system with periods of 1 to 10,000 selectable.

REAI)TE BEFORE TESTING

TESTING PROCEDURE

I. First Test

A. Connect to receiver

(NOTE 1) B. Supply pwr at 12.00 ± .05 V

C. Measurements (Compare to nominal and record measured)

1. DC Voltages — Nominal

DC Voltages	Nominal
PT. 1 "ON"	12.00 ± .05
PT. 2 "E3D"	9.2 ± 0.1
PT. 3 C5 (+SIDE)	5.1 ± 0.1
PT. 4 "TEMP"	4.7 ± 0.2 (room temperature)
PT. 5 "AUDIO"	2.3 ± 0.2
PT. 6 "SQUIB (TM)"	3.99 ± 0.04

(PT.6 measured with lamp load (Note 2) between Pt. 7 "SQUIB" output and Pt. 1 "ON")

2. AC Voltage w/oscilloscope (10MΩ PROBE)

PT. 8 "TP2" 1 VPP Noise ± .3V
PT. 5 "AUDIO" " " plus 2.3 V DC offset

3. Measure frequency at PT. 9-(PIN 3 + 4, ICI)- F_o=300 ± 50 H_Z

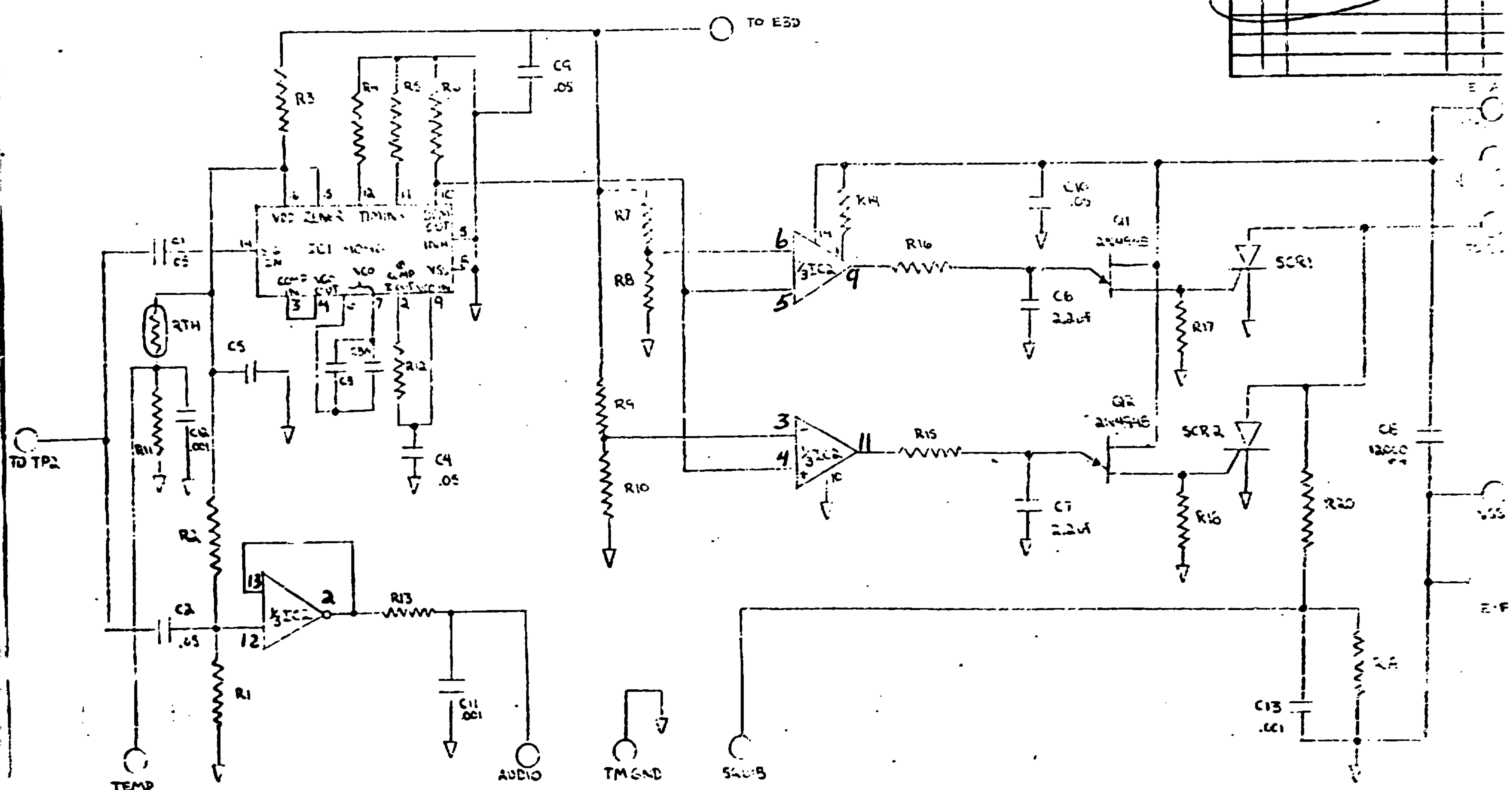
4. Turn on RF and adjust freq. if necessary
PT. 5 "AUDIO" check for full quieting.
Adjust modulation to maximum and record amplitude (IVPP Nominal)

5. Send command (freq. sweep 250 H_Z-400 H_Z and hold)
Check lamp turn on
Reset command freq. to 250 H_Z
Convert lamp load to PT. 10 and PT. 1 "ON"

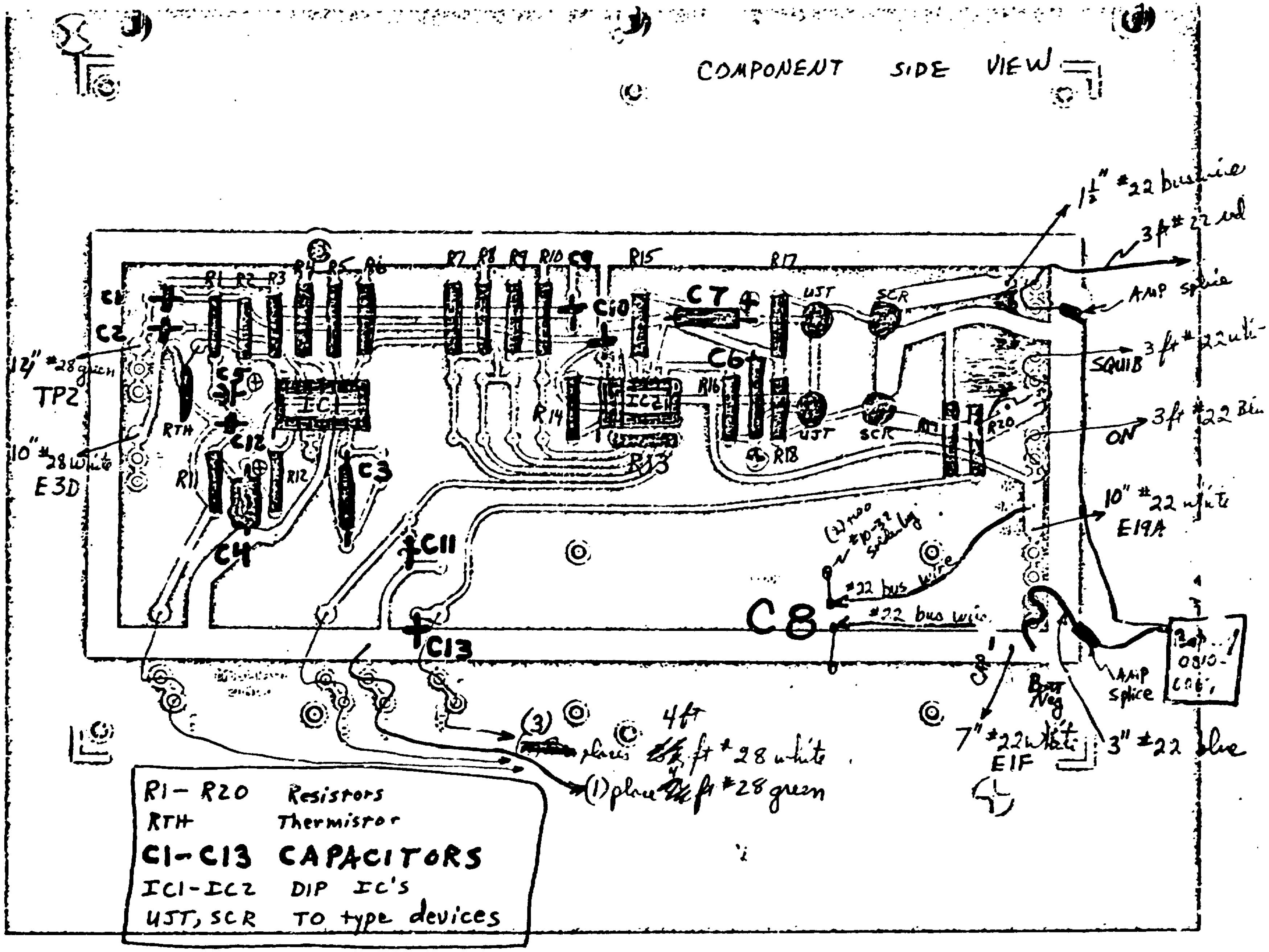
6. AC at PT. 5 "AUDIO" check for 1/2 noise level reduction while reducing pwr supply voltage and record volts.

Notes: (1) A very large capacitor is connected to the input so care must be taken when turning on power to limit the input current. The lamp load can be momentarily connected between the "ON" wire and the power supply or battery until the lamp dims and then the power supply (or battery) can safely be connected quickly to the receiver.

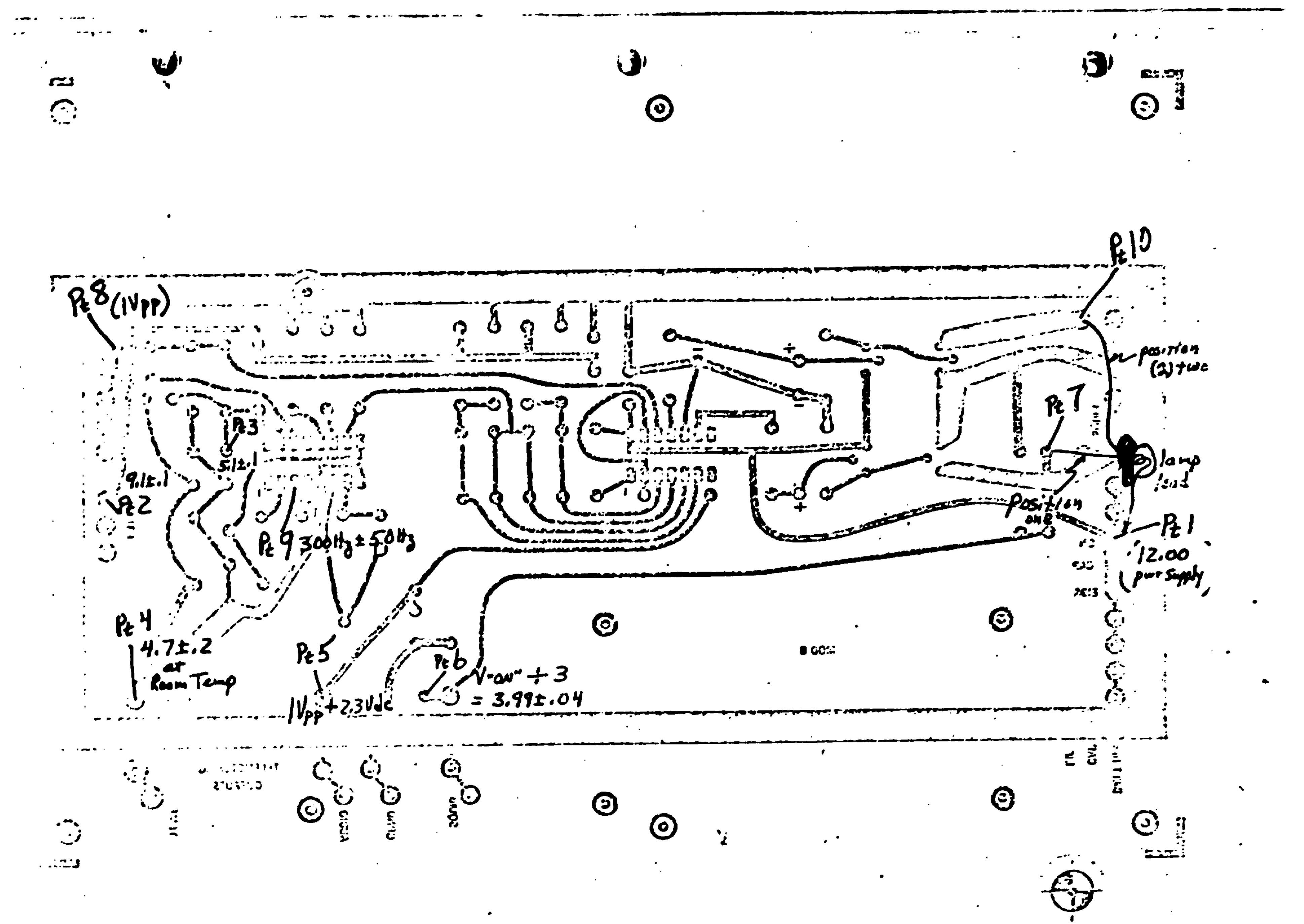
(2) "LAMP LOAD" is a Dialco 14V 80 MA lamp #507-3914 with alligator clips on 2" leads.



TOLERANCES			
DECIMAL		SCALE	DRAWN BY / APPROVED BY
FRACTIONAL	TITLE: Command Decoder / Receiver Board		
ANGULAR	DATE: 15 Dec 75	DRAWING NUMBER	



COMPONENT SIDE VIEW
R1 R2 R3 R4 R5 R6 R7 R8 R9 R10 C9 R15 R17
C1
C2
C10
C7
C6
UJT
SCR
IC1
IC2
R14
R16
R13
R18
R20
RTH
C12
C3
R11
R12
C4
C11
C13
C8
12" #28 green
TP2
10" #28 white
E3D
1½" #22 bus wire
3 ft #22 red
AMP splice
SQUIB 3 ft #22 white
ON 3 ft #22 Blu
10" #22 white
E19A
#22 bus wire
#22 bus wire
Batt Neg
AMP splice
3" #22 blue
7" #22 white
E1F
(3) places 4 ft #28 white
(1) place 4 ft #28 green
R1 - R20 Resistors
RTH Thermistor
C1-C13 CAPACITORS
IC1-IC2 DIP IC's
UJT, SCR TO type devices



Pt 8 (1Vpp)
Pt 10
position (2) twc
Pt 7
lamp
Pt 3
5.1±.1
9.1±.1
Pt 2
Pt 9 300Hz ± 50Hz
Position one
Pt 1
12.00 (pwr supply)
Pt 4
4.7±.2 at Room Temp
Pt 5
1Vpp + 2.3Vdc
Pt 6
V"on" ÷ 3 = 3.99±.04

Parts List Mod B

Part	Description	No. Required
R1	1M ΩCC*	1
R2	1.3M CC	1
R3, R13	10K mf	2
R4, R7, R9	226k mf**	3
R5, R8, R10	63.4k mf	3
R6	511 k mf	1
R12	1.8M CC	1
R14, R15, R16	820 k CC	3
R17, R18	20 CC	2
R19	49.9K mf	1
R20, R11	100k mf	2
RTH	10k mf	1
C1, C2, C9, C10	.047 CD	4***
C3	.047 TRW x 483 W2 ± 5%	1
C4	.22 10V CSR 13	1
C5	47 Sprague 1960	1
C6, C7	2.75 CSR13 15V	2
C8****	4,000 Microfared 15V Sprague 602D	1
C11, C12, C13	.001	3
IC1	CD4046AD RCA	1
IC2	L144AP Siliconix	1
Q1, Q2	2N4948 UJT	2
SCR1, SCR2	S2600 SCR	2
PC1	Plectron P700 Special Receiver Board	1
PC2	Encoder Board Mod B	1
RF1	Lark Coax rf Filter SF 138-14-3EE	1
B1	LMB box 787	1

Part	Description	No. Required
BATT	GATES 12V 2.5Ah 0810-0067	1
Hardware	6-32 x 1/4 RHMS (Cd)	4
	6-32 x 2-1/2 RHMS (Cd)	6
	6-32 x 2 insulated spacer HH Smith #2134	6
	6-32 x 5/8" stand off HH Smith	4
	6-32 hex nut nylon	2
	6-32 insulated washer	1
	6-32 solder lug	1
	10-32 solder lug	2
	3/8" rubber ommet	1
	scotch #850 transparent	1 roll
	filament tape	15 ft
	Urethane foam 1" thick	3-3/4 sq ft
	aluminized Mylar 2 mil. one Sect.	4 running ft
	Elmer's GlueAll	
	#22 Teflon hookup wire	
	Red	3 ft
	Blue	3 ft 6 in
	White	4 ft 6 in
	#28 Teflon hookup wire	
	Green	5 ft
	White	13 ft
	Cable assembly 9 ft RG188 male BNC to male BNC	1
	Expoxylite #9653 Polyurethane circuit coating	
	braided shield 1/4" ID Belden 8660	21"
	Amp Butt Splice 34070	2
	Polyurethane Stycast ~~34070~~	
	Emerson & Cumming, Inc.	

* CC are all carbon composition ± 5% tolerance 1/4 watt resistors made by IRC or TRW

** mf are all metal film ± 1% tolerance RN60C or RN55C resistors

***CD are all ceramic disc capacitors 15VDC minimum with 0.250 inch lead spacing such as Sprague Hypercon C069B160H473Z

****C8 can be any value between 4,000 microfared and 18,000 microfrared in the same series and voltage rating

END

DATE

FILMED